TO ACCOUNT FOR THE EFFECTS OF AEROSOLS IN CLIMATE MODELS:

- Need the column extinction **optical depth** (τ_a)

  -- Currently the state-of-the-art for operational satellite retrievals

- Need mean effective aerosol **microphysical properties**

  -- Single scattering **phase function** and **albedo**

  -- These map to **Size Distribution** (r_a), **Shape**, and **Indices of Refraction** (nr, ni)

- Need aerosol **vertical distribution**

Summary: Need constraints on [τ_a, r_a, **nr, ni**] & shape

New Multiangle Capability -- More Information about Aerosols

How will MISR contribute to the global aerosol picture needed for climate change studies?

Based on simulations over cloud-free, calm ocean, for pure particle types:

- **Aerosol Extinction Optical Depth (τ_a)**

  -- Determined to at least 0.05 or 20%, whichever is larger, for common aerosol types except soot, even when the particle microphysical properties are poorly known.

- **Particle Size (r_a)**

  -- "Small," "Medium," and "Large" size discrimination across Accumulation Mode sizes -- key for vis spectrum

- **Indices of Refraction (nr, ni)**

  -- Two to four compositional groups

- **Spherical vs. Nonspherical** for Sahara dust indices

- **Poorer Sensitivity for ni >~ 0.008 (Black Carbon)**

How can MISR contribute?

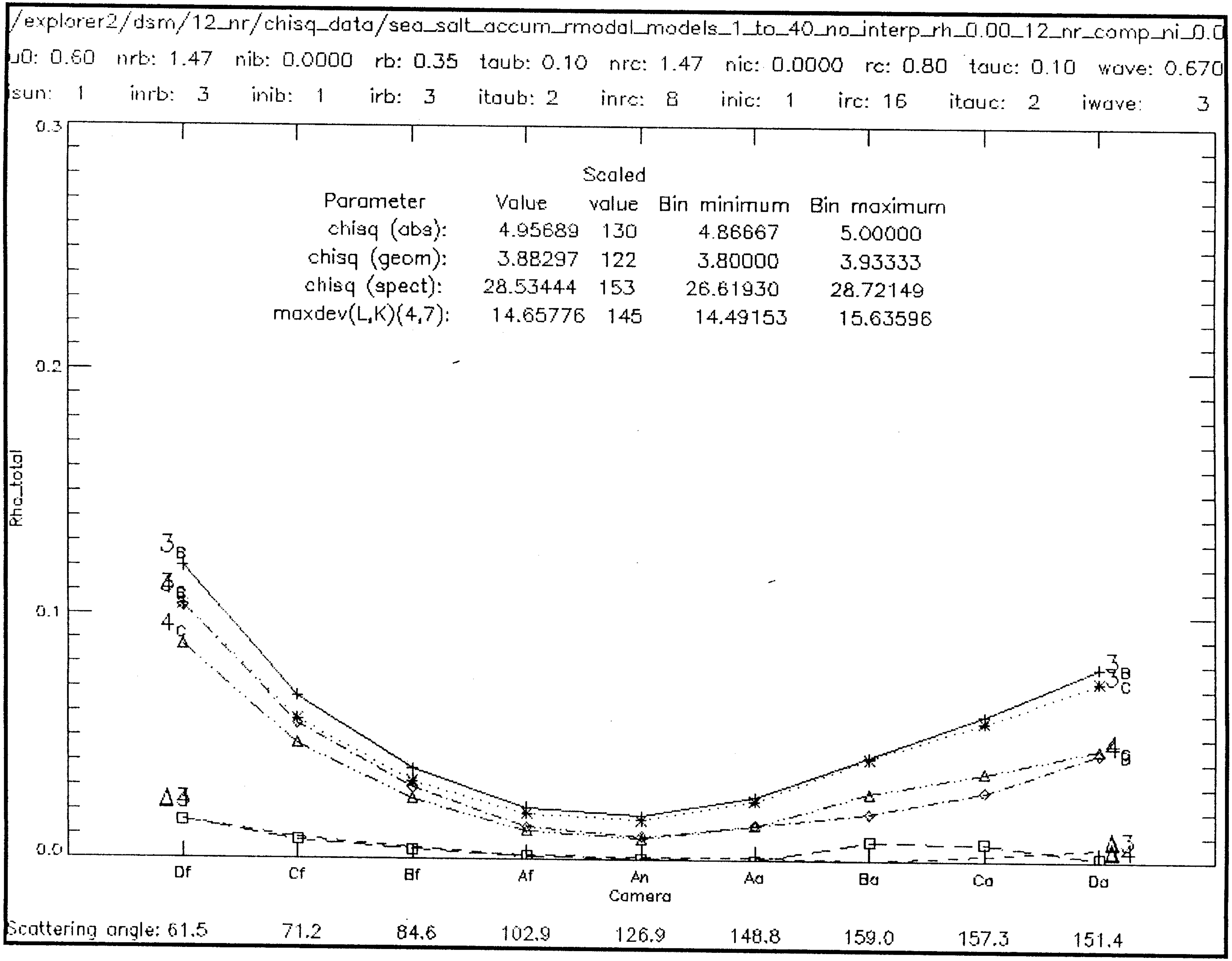
- **Can not** in general **nail down everything** we need to know to model the effects of aerosols, even over cloud-free, calm ocean, without introducing other information

- **Can distinguish air masses** containing different aerosol types – a major step beyond current operational satellite aerosol retrievals, which obtain only optical depth, based on entirely assumed particle properties

Use **MISR to get the large-scale, time-varying picture** of air masses containing different aerosol types

Rely on **field measurements to give detailed microphysical properties** of aerosol within each air mass

====> **Complementary Efforts**



/explorer2/dsm/12_nr/chisq_data/sea_salt_accum_rmodal_models_1_to_40_no_interp_rh_0.00_12_nr_comp_ni_0.0
u0: 0.60 nrb: 1.47 nib: 0.0000 rb: 0.35 taub: 0.10 nrc: 1.47 nic: 0.0000 rc: 0.80 tauc: 0.10 wave: 0.670
isun: 1 inrb: 3 inib: 1 irb: 3 itaub: 2 inrc: 8 inic: 1 irc: 16 itauc: 2 iwave: 3
Scaled
Parameter Value value Bin minimum Bin maximum
chisq (abs): 4.95689 130 4.86667 5.00000
chisq (geom): 3.88297 122 3.80000 3.93333
chisq (spect): 28.53444 153 26.61930 28.72149
maxdev(L,K)(4,7): 14.65776 145 14.49153 15.63596
Rho_total
0.3
0.2
0.1
0.0
Df
Cf
Bf
Af
An
Aa
Ba
Ca
Da
Camera
Scattering angle: 61.5 71.2 84.6 102.9 126.9 148.8 159.0 157.3 151.4

Evaluating Agreement Between Comparison Models and "Measurements"

4 Parameters are used to summarize the information in **18 Measurements**

χ^2_{abs} is defined as:

$$\chi^2_{abs} = \frac{1}{N\langle w_k \rangle} \sum_{l=3}^{4} \sum_{k=1}^{9} \frac{w_k \left[\rho_{meas}(l,k) - \rho_{comp}(l,k) \right]^2}{\sigma^2_{abs}(l,k)} \qquad (1)$$

where ρ_{meas} is the simulated "measured" radiance, ρ_{comp} is the simulated radiance for the "assumed" comparison model, l and k are the indices for wavelength band and camera, N is the number of measurements included in the calculation, and σ_{abs} is the absolute measurement error in the radiance. w_k is the weight for terms related to camera k, and $<w_k>$ is the average of the weights for all the cameras included in the sum.

χ^2_{geom} is defined as:

$$\chi^2_{geom} = \frac{1}{N\langle w_k \rangle} \sum_{l=3}^{4} \sum_{\substack{k=1 \\ k \neq nadir}}^{9} \frac{w_k \left[\frac{\rho_{meas}(l,k)}{\rho_{meas}(l,nadir)} - \frac{\rho_{comp}(l,k)}{\rho_{comp}(l,nadir)} \right]^2}{\sigma^2_{geom}(l,k)} \qquad (2a)$$

Here σ^2_{geom} is the uncertainty in the camera-to-camera equivalent reflectance :

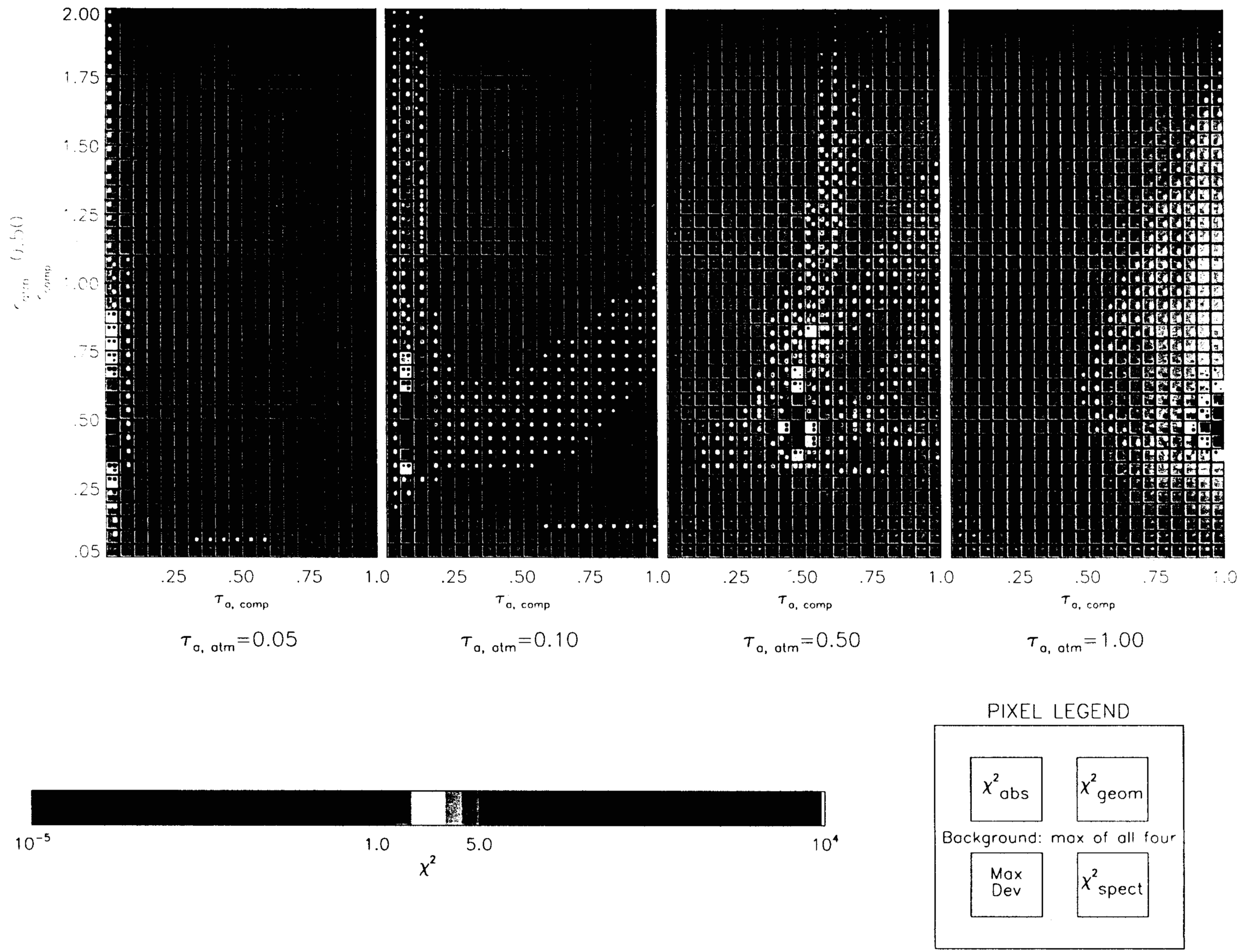
$$\sigma^2_{geom}(l,k) = \frac{\sigma^2_{cam}(l,k)}{\rho^2_{meas}(l,nadir)} + \frac{\sigma^2_{cam}(l,nadir)\ \rho^2_{meas}(l,k)}{\rho^4_{meas}(l,nadir)} \qquad (2b)$$

$\sigma_{cam}(l,k)$ is the contribution of (band l, camera k.) to the camera-to-camera relative calibration reflectance uncertainty.

Also, χ^2_{spec} (similar to χ^2_{geom}, but normalized to band 3) and χ^2_{maxdev}, which is largest term in (1).

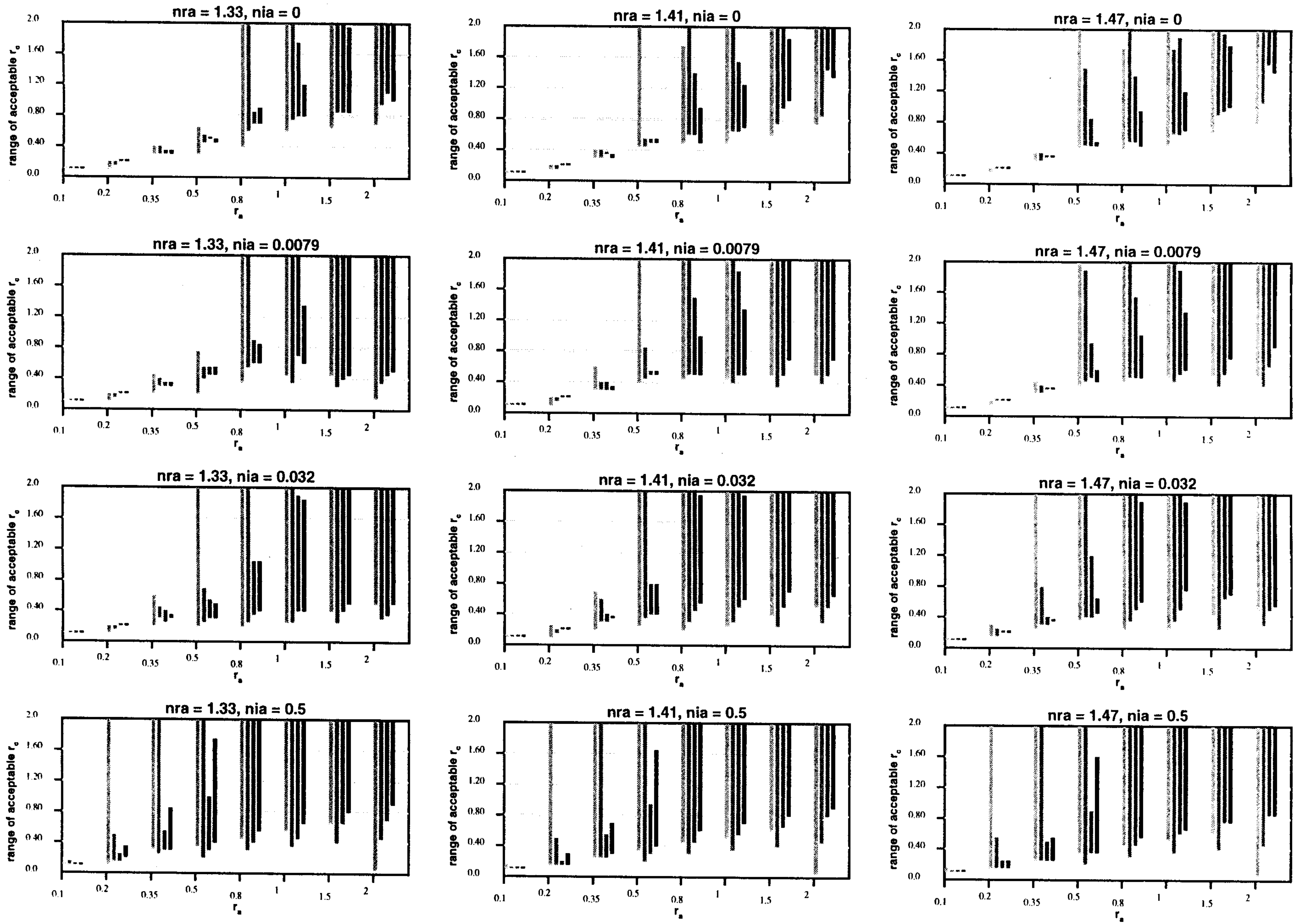
N_r 1.53 N_i 0.0 Atmosphere and Comparison (Fresnel Surface)

RH atm = 0.70 RH comp = 0.70 μ_0 = 0.60 $\Delta\phi$ = 26.0



sulfate_1_accum_rm_0.2_rh_0.70_N_vary_nr_1.53_ni_0.0000_lambda_0.670_0.865_mu0_0.60_interp.bin

Sat Dec 13 21:57:37 1997



nra = 1.33, nia = 0
nra = 1.41, nia = 0
nra = 1.47, nia = 0
nra = 1.33, nia = 0.0079
nra = 1.41, nia = 0.0079
nra = 1.47, nia = 0.0079
nra = 1.33, nia = 0.032
nra = 1.41, nia = 0.032
nra = 1.47, nia = 0.032
nra = 1.33, nia = 0.5
nra = 1.41, nia = 0.5
nra = 1.47, nia = 0.5
range of acceptable r_c
r_a
0.1
0.2
0.35
0.5
0.8
1
1.5
2
0.0
0.40
0.80
1.20
1.60
2.0

The Need for a Climatological Retrieval

The "Generic" Retrieval obtains column mean weighted aerosol properties with a minimum of assumptions

- Indicates the "Information Content" of the data
- May not produce properties that apply to any particles actually in the atmosphere

  -- Difficult to check against field measurements

  -- Difficult to check against expected sources (models)

===> Natural populations are mixes

The "Climatological" Retrieval assumes pure particle properties and derives the range of mixes that match the observations

- The results depend on the quality of the assumed climatology
- Needed to identify air mass source regions
- Needed to track the evolution of air mass as they are advected downstream from sources
- Needed to compare MISR data with aerosol transport models
- Needed to compare MISR data with in situ sampling

Monthly, Global Aerosol Transport Model Results Used

Aerosol Type	Source	Reference	Spatial Resolution	Quantities Reported	Factor Used to Convert Mass to τ
Accumulation and Coarse **Mineral Dust**	GISS	Tegen & Fung (1995)	4° x 5°	Total Column Dust Optical Depth, regrouped into 2 size bins: < 1 micron (accumulation) 1 to 10 micron (coarse)	1.5 m^2/gm (accum. mode); 0.3 x m^2/gm (coarse mode)
Sea Salt	GISS	Tegen et al. (1997)	4° x 5°	Total Column Aerosol Optical Thickness	0.3 m^2/gm
Sulfates	LLNL	Liousse et al. (1996)	~ 4.5° x 7.5°	Column Mass Load (gm/m^2)	8.5 m^2/gm
Carbonaceous Particles	GISS	Liousse et al. (1996)	4° x 5°	Total Column Aerosol Optical Thickness	8.0 m^2/gm
Black Carbon	GISS	Liousse et al. (1996)	4° x 5°	Total Column Aerosol Optical Thickness	9. m^2/gm

Major Climatological Particle Mixing Groups

Classification	Component 1	Component 2	Component 3	Component 4	Color
1. Carbonaceous + Dusty Maritime	Sulfate	Sea Salt	Carbonaceous	Accumulation Mode Dust	Blue
2. Dusty Maritime + Coarse Dust	Sulfate	Sea Salt	Accumulation Mode Dust	Coarse Dust	Yellow
3. Carbonaceous + Black Carbon Maritime	Sulfate	Sea Salt	Carbonaceous	Black Carbon	Green
4. Carbonaceous + Dusty Continental	Sulfate	Accumulation Mode Dust	Coarse Dust	Carbonaceous	Red-Brown
5. Carbonaceous + Black Carbon Continental	Sulfate	Accumulation Mode Dust	Carbonaceous	Black Carbon	Gray

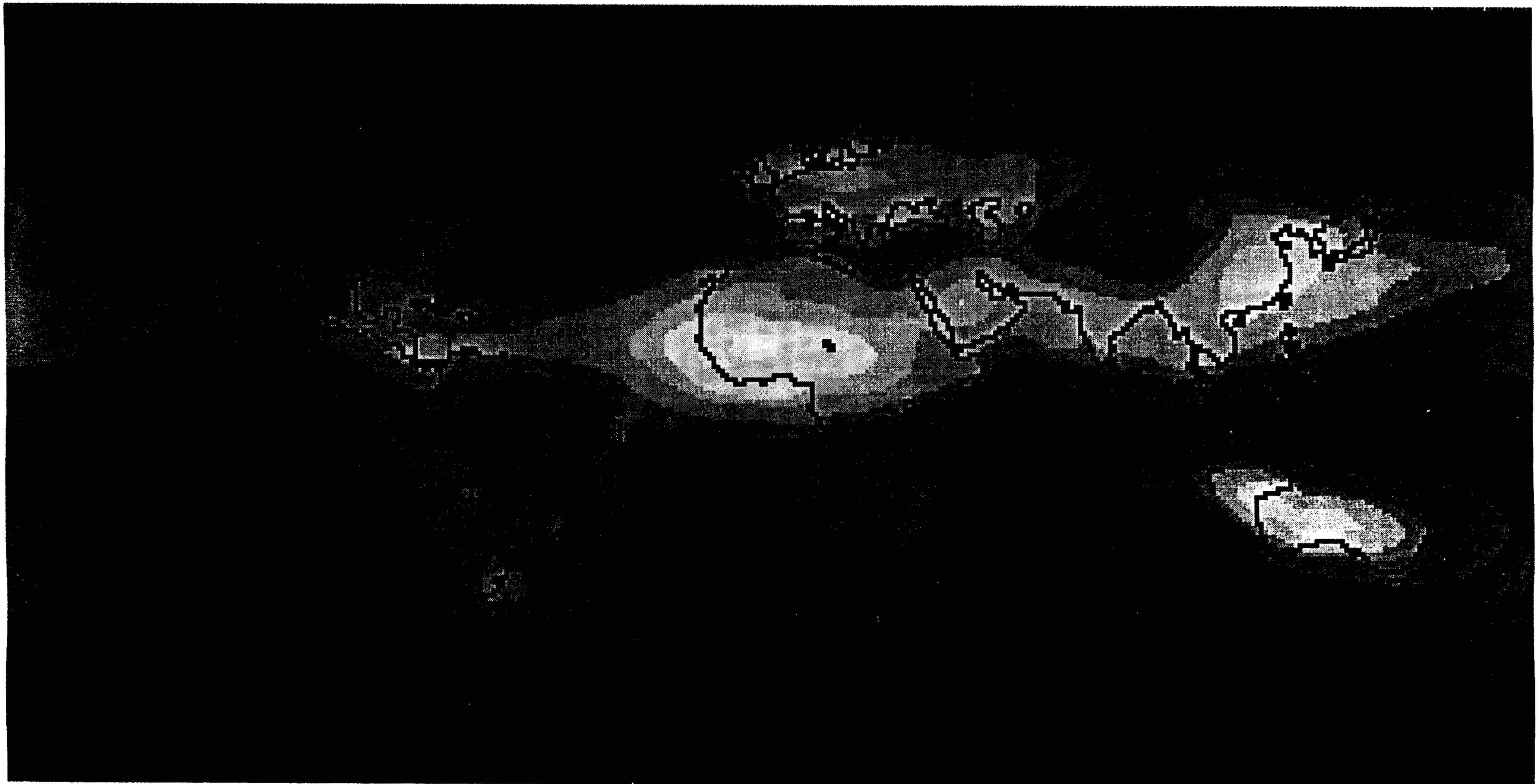

lat=-89 lon=-180 pixel=4 Tau_tot=0.007322 month=January


lat=-89 lon=-180 pixel=22 Tau_tot=0.005465 month=July

Particle Mixture Classification Scheme

Classification	Component 1	Component 2	Component 3	Component 4	Color
1. Carbonaceous + Dusty Maritime	**Sulfate**	**Sea Salt**	**Carbonaceous**	**Accumulation Mode Dust**	**Blue**
1a.	**0.67**	0.13	0.10	0.10	
1b.	0.41	0.13	**0.27**	**0.19**	
1c.	0.40	**0.32**	0.17	0.11	
2. Dusty Maritime + Coarse Dust	**Sulfate**	**Sea Salt**	**Accumulation Mode Dust**	**Coarse Dust**	**Yellow**
2a.	**0.52**	0.17	0.21	0.10	
2b.	0.29	0.13	**0.39**	**0.19**	
3. Carbonaceous + Black Carbon Maritime	**Sulfate**	**Sea Salt**	**Carbonaceous**	**Black Carbon**	**Green**
3a.	**0.51**	0.18	0.26	0.05	
3b.	0.35	0.10	**0.47**	**0.08**	
4. Carbonaceous + Dusty Continental	**Sulfate**	**Accumulation Mode Dust**	**Coarse Dust**	**Carbonaceous**	**Red-Brown**
4a.	**0.61**	0.21	0.05	0.13	
4b.	0.40	**0.35**	0.09	**0.16**	
4c.	0.22	**0.51**	**0.16**	0.11	

5. Carbonaceous + Black Carbon Continental	Sulfate	Accumulation Mode Dust	Carbonaceous	Black Carbon	Gray
5a.	**0.59**	0.12	0.23	0.06	
5b.	0.25	0.12	**0.54**	0.09	
5c.	0.44	**0.23**	**0.26**	0.07	



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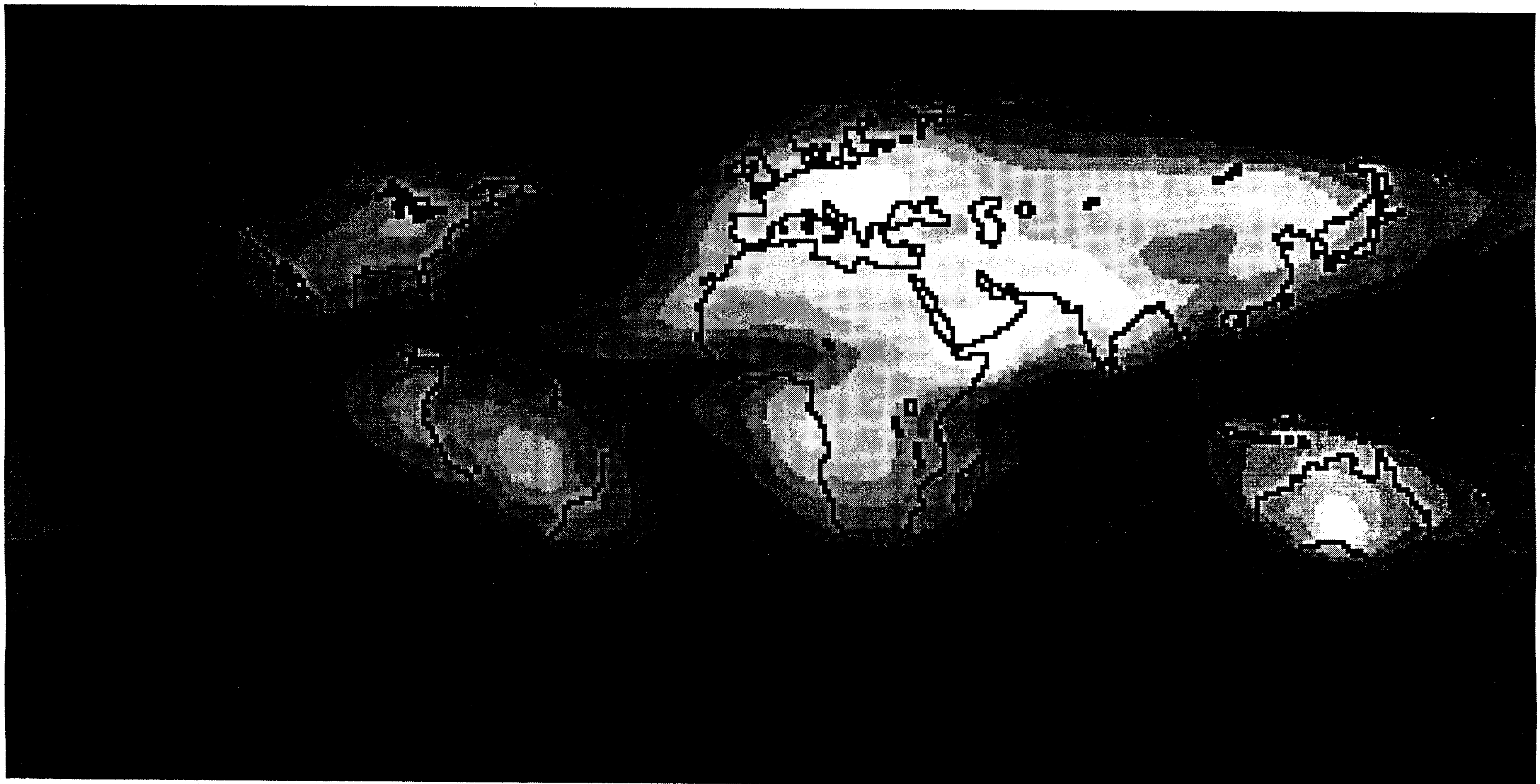
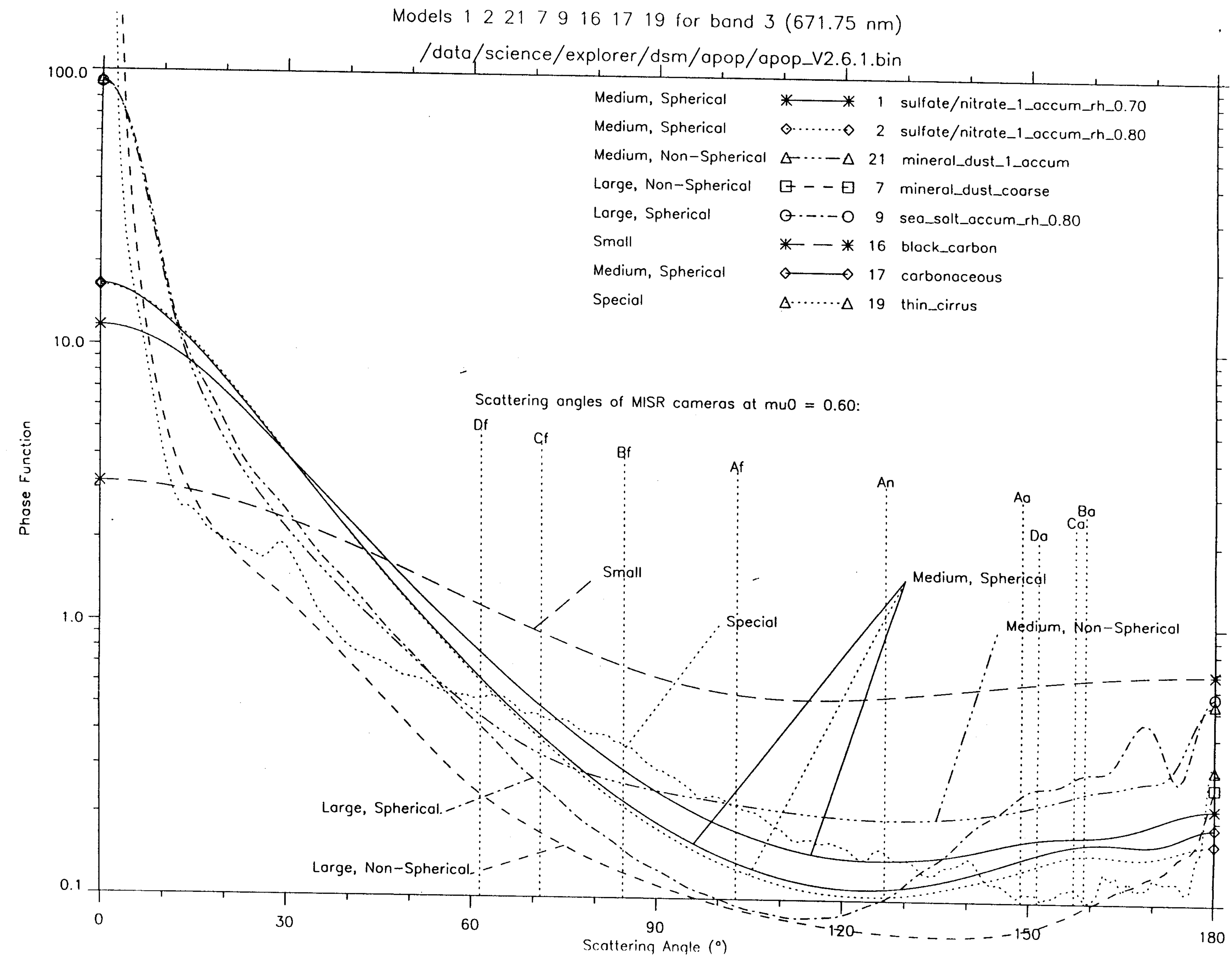


lat=-89 lon=-180 pixel=12 Tau_tot=0.005465 month=July

Assumed Physical Properties of Component Particles§

	n_r	n_i	r_c	ω_0	Size / Shape Category
Thin Cirrus	1.31	0.0	>50.	1.0	Special
Sea Salt	1.35	0.0	0.61	1.0	Large Spherical
Sulfate (Land)	1.46	0.0	0.08	10.	Medium Spherical
Sulfate (Ocean)	1.39	0.0	0.10	1.0	Medium Spherical
Carbonaceous	1.43	0.0035	0.13	0.98	Medium Spherical
Mineral Dust (Accumulation Mode)	1.53	0.0045	0.47	0.91	Medium Nonspherical
Mineral Dust (Coarse Mode)	1.53	0.0045	1.90	0.73	Large Nonspherical
Black Carbon	1.75	0.440	0.012	0.17	Small

§ Optical properties reported for MISR Band 3 (670 nanometers). For hygroscopic particles, the hydrated values are shown.



Models 1 2 21 7 9 16 17 19 for band 3 (671.75 nm)
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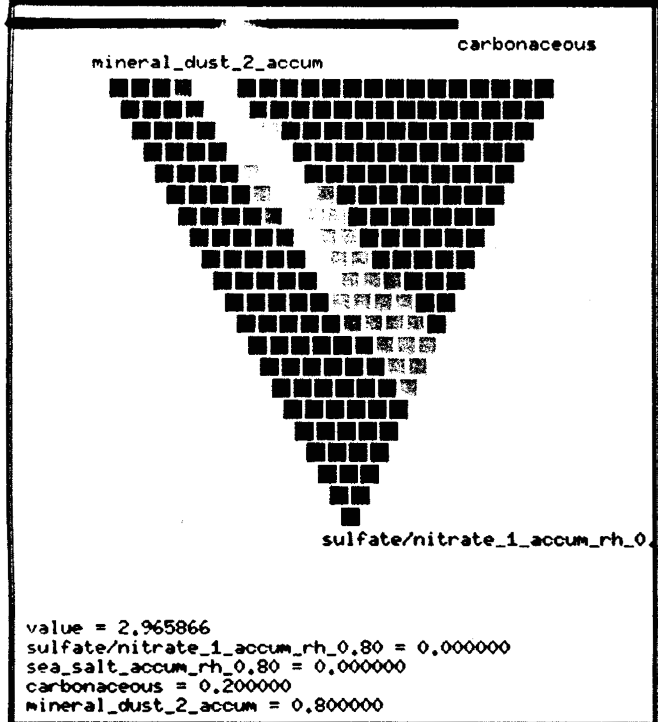
Medium, Spherical 1 sulfate/nitrate_1_accum_rh_0.70
Medium, Spherical 2 sulfate/nitrate_1_accum_rh_0.80
Medium, Non-Spherical 21 mineral_dust_1_accum
Large, Non-Spherical 7 mineral_dust_coarse
Large, Spherical 9 sea_salt_accum_rh_0.80
Small 16 black_carbon
Medium, Spherical 17 carbonaceous
Special 19 thin_cirrus
Scattering angles of MISR cameras at mu0 = 0.60:
Df
Cf
Bf
Af
An
Aa
Da
Ca
Ba
Small
Special
Medium, Spherical
Medium, Non-Spherical
Large, Spherical
Large, Non-Spherical
Phase Function
Scattering Angle (°)
100.0
10.0
1.0
0.1
0
30
60
90
120
150
180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mineral_dust_2_accum
sulfate/nitrate_1_accum_rh_0.
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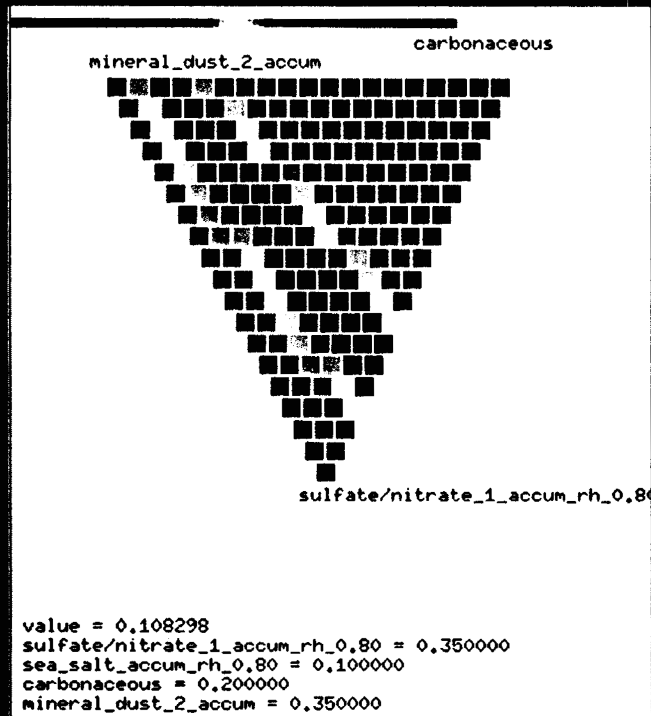
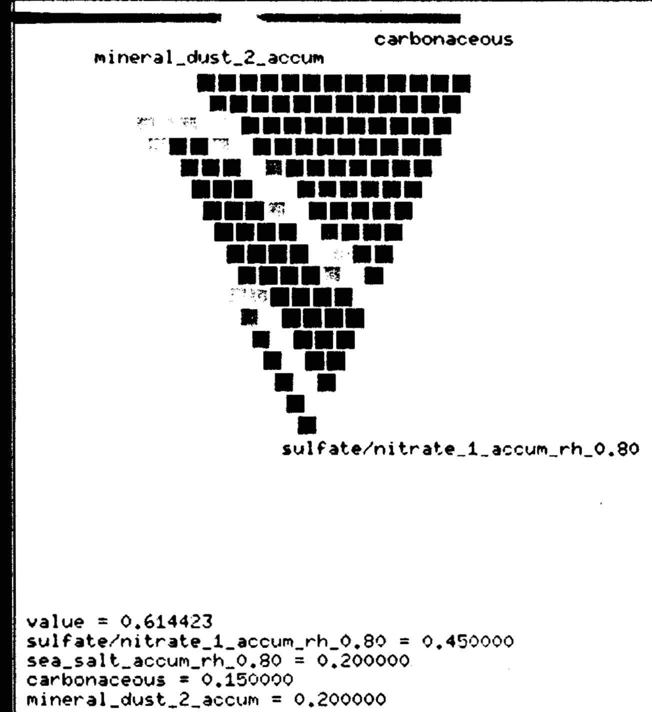
carbonaceous = 0.200000
mineral_dust_2_accum = 0.800000


carbonaceous
mineral_dust_2_accum
sulfate/nitrate_1_accum_rh_0.8
value = 0.108298
sulfate/nitrate_1_accum_rh_0.80 = 0.350000
sea_salt_accum_rh_0.80 = 0.100000
carbonaceous = 0.200000
mineral_dust_2_accum = 0.350000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mineral_dust_2_accum
sulfate/nitrate_1_accum_rh_0.80
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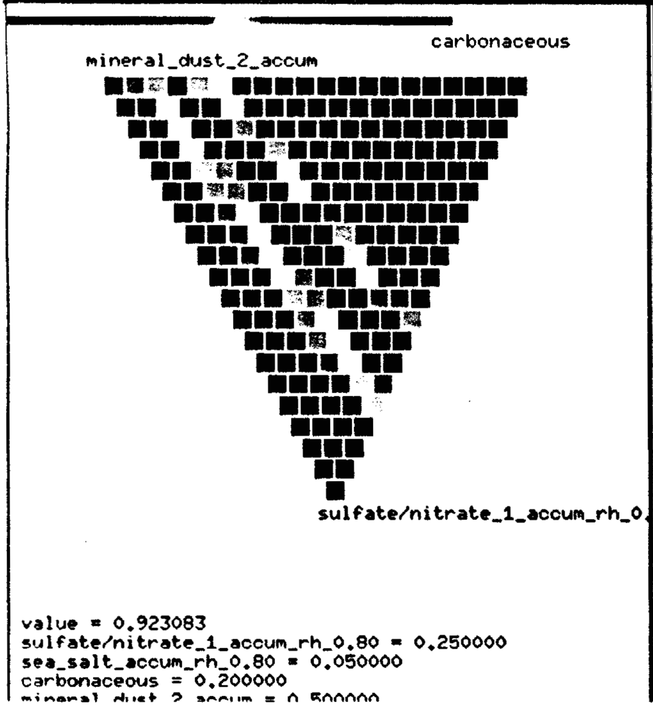
sea_salt_accum_rh_0.80 = 0.200000
carbonaceous = 0.150000
mineral_dust_2_accum = 0.200000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mineral_dust_2_accum
sulfate/nitrate_1_accum_rh_0.
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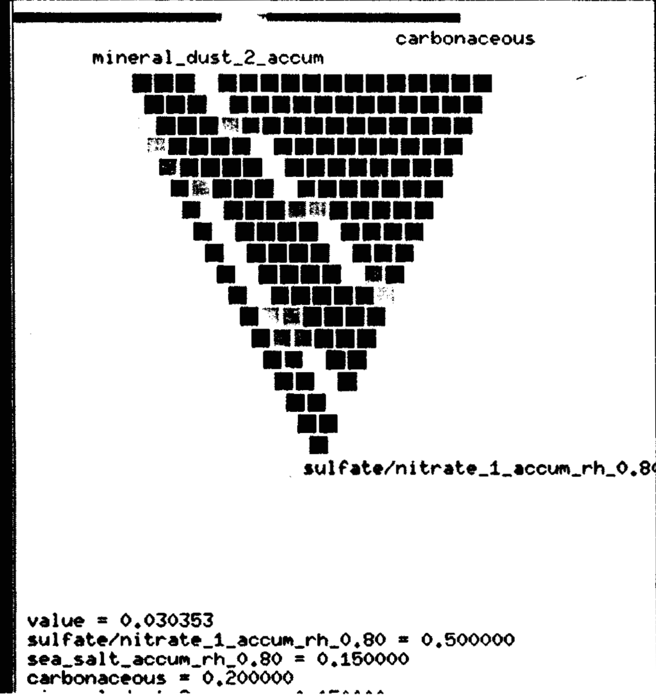
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mineral_dust_2_accum
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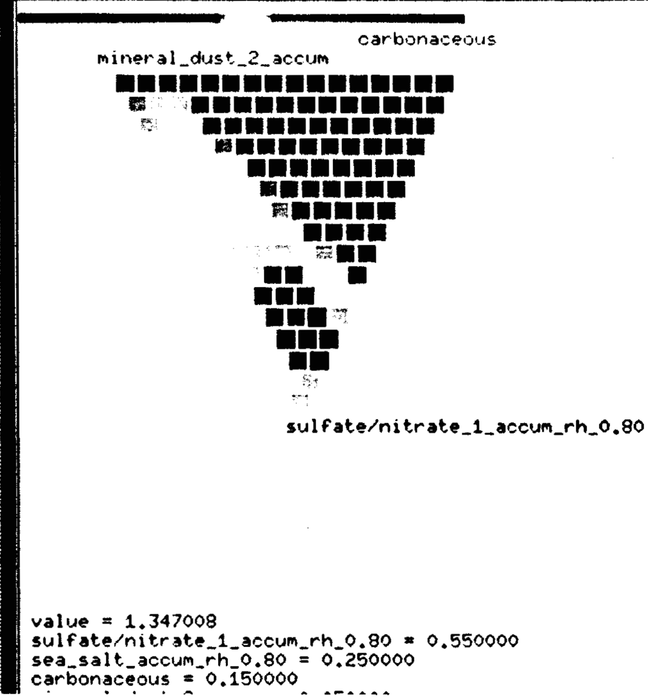
carbonaceous = 0.200000


carbonaceous
mineral_dust_2_accum
sulfate/nitrate_1_accum_rh_0.80
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sea_salt_accum_rh_0.80 = 0.250000
carbonaceous = 0.150000

Overall Program for MISR Pre-Launch Sensitivity Studies

1. Sensitivity to the difference between **Spherical and NonSpherical** Particles with "Mineral Dust" indices of refraction and particle size ranges.

JGR 102, D14, pages 16,861 - 16,870.

2. Sensitivity to the differences in **optical depth**, **characteristic radius**, and **indices of refraction** for Pure Particle Types.

JGR 103, D24, pages 32,195 - 32,213.

3. Sensitivity to natural **Mixes** of Particles.

JGR, to be submitted, Sept., 1999.

4. Constraints that MISR, MODIS, SAGE III, and CERES can make to the Cloud-free **Reflected Solar Radiation Flux**.

Joint Project: Kahn, West, Ackerman, Clothiaux, Martonchik, Strahler, Schaaf, Strugnel, Lucht

In progress.

5. **AirMISR Retrieval** Over Dark Water.

In progress.